Need for High Resolution X-ray Spectroscopy with Constellation-X: Implications of Covering Factor Analysis of NGC 3783

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Introduction

High resolution and signal to noise spectral observations of AGN outflows in the UV demonstrate the need for using covering factor models in calculating absorber column densities. Non-solar abundances could affect photoionization models, total column density, and outflow energy.

We study the best X-ray data set of an AGN outflow, the Chandra 900 kilosecond observation of NGC 3783, for similar effects in the strongly saturated line series of Ne X and O VII. These lines and others are modeled assuming full covering, constant partial covering, as well as a velocity dependent covering factor.

We generate synthetic data for the future Con-X mission and compare to the Chandra 900 ks data. The results from our covering factor analysis motivated us to explore simulations of higher resolution absorption profiles.

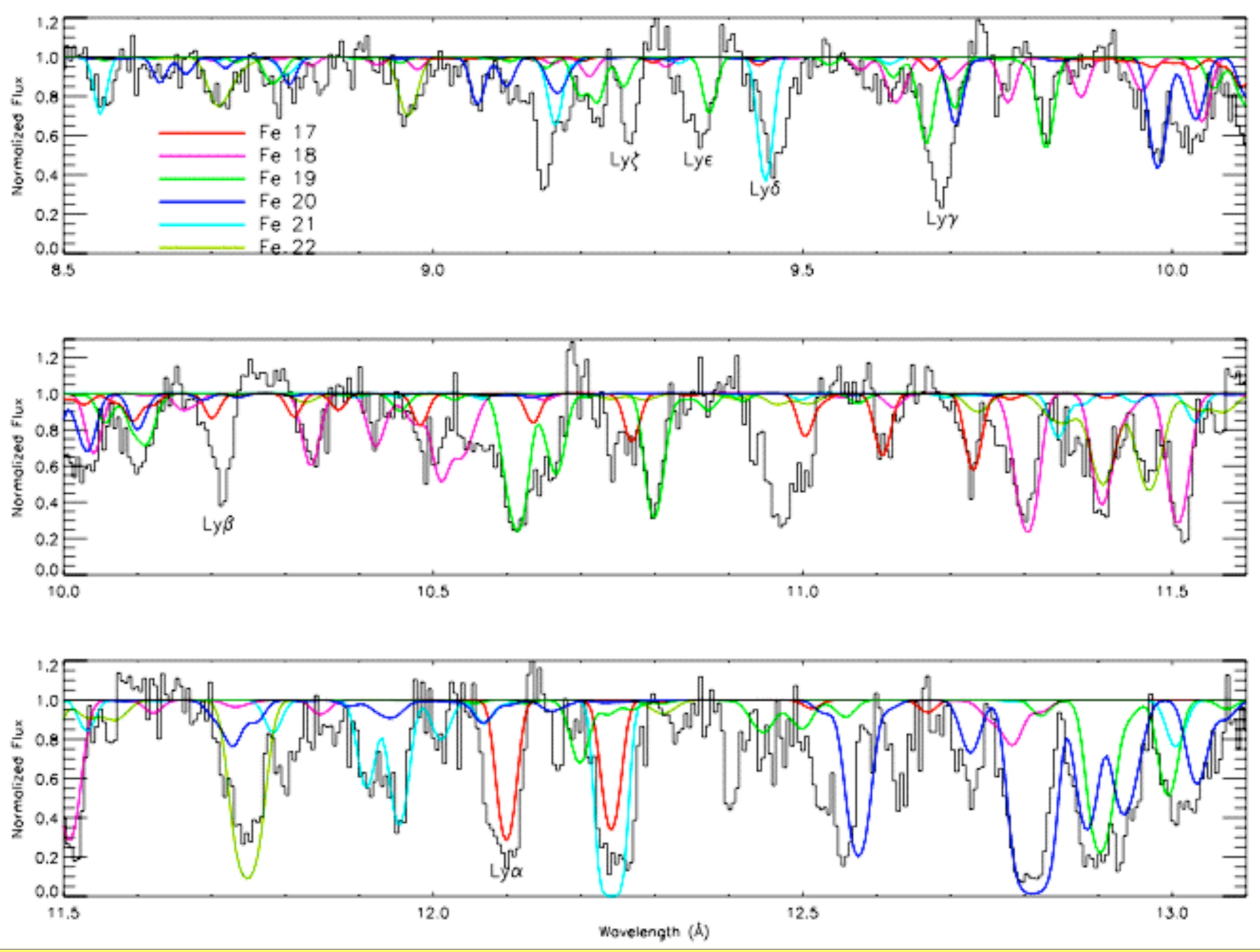

Figure 1: Theoretical Fe absorption spectra (for C=1) plotted over the normalized Chandra 900 ks NGC 3783 spectrum (histogram). Pure lines of the Ne X-contaminating Fe series are fit with gaussian τ profiles, and the colored lines represent the absorption spectra of each ion scaled to the fits by $f\lambda$ ratios.

Method

Approximating τ as a gaussian profile scaled with $f\lambda$ ratios, we create line series absorption profiles according to the covering factor model we wish to fit for. This is convolved with instrumental resolution and Levenberg-Marquardt least-squares fits are performed to the series data. Errors are calculated from integrated photon counts. For highly saturated line series, we use the lowest-order line as 1-C(v).

This method was tested on the Si and S line series in the 4 - 7 Å range for comparison with previous analyses, agreeing within the errors.

For Chandra/Con-X simulations we generated absorption profiles from full covering, C=0.8, and two-component C(v) models. These were convolved with an instrument resolution similar to the MEG and proposed Con-X grating resolution $\lambda/\delta\lambda$ of 3000. Noise was generated using Poisson statistics for the S/N of the 900 ks observation for our MEG simulation. For the Con-X data we assumed a collecting area of 3000 cm^2 and a 90 ks observation.

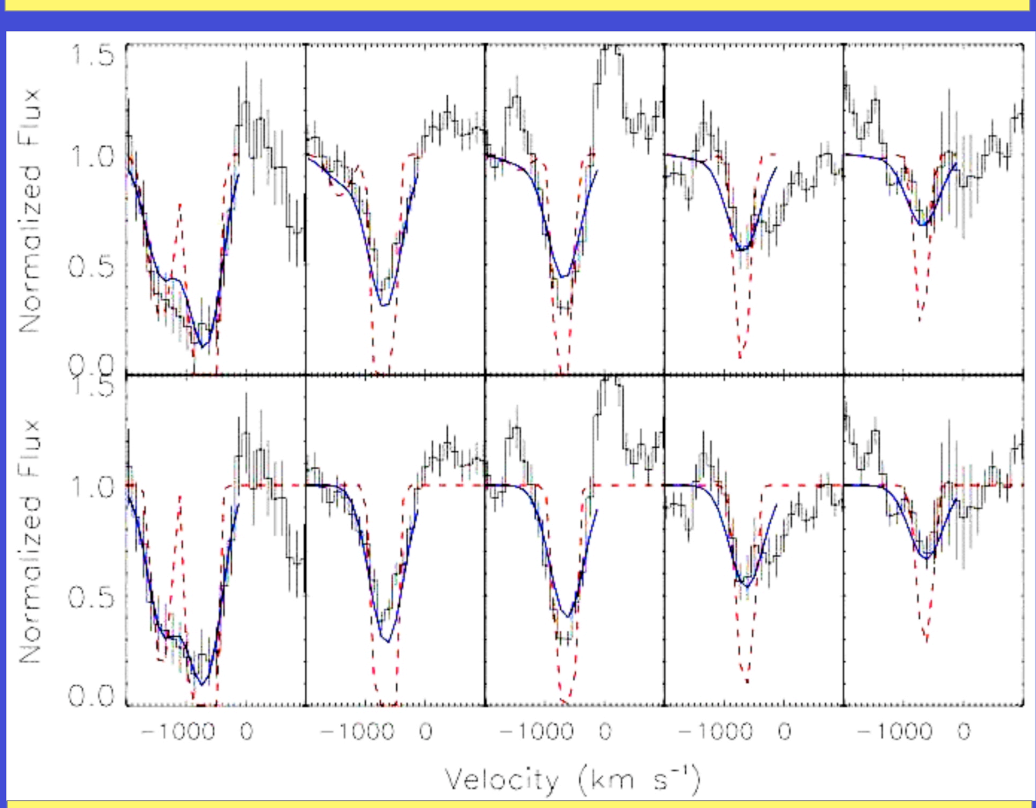

Figure 2: Contaminant-removed line centers of Ne X Lyman α through ε (left to right) are fit with two-component gaussians. Instrument resolution is included in fit for full covering (top) and Lyα covering factor (bottom). Pure profile is shown in dashed red, instrument-convolved line in blue.

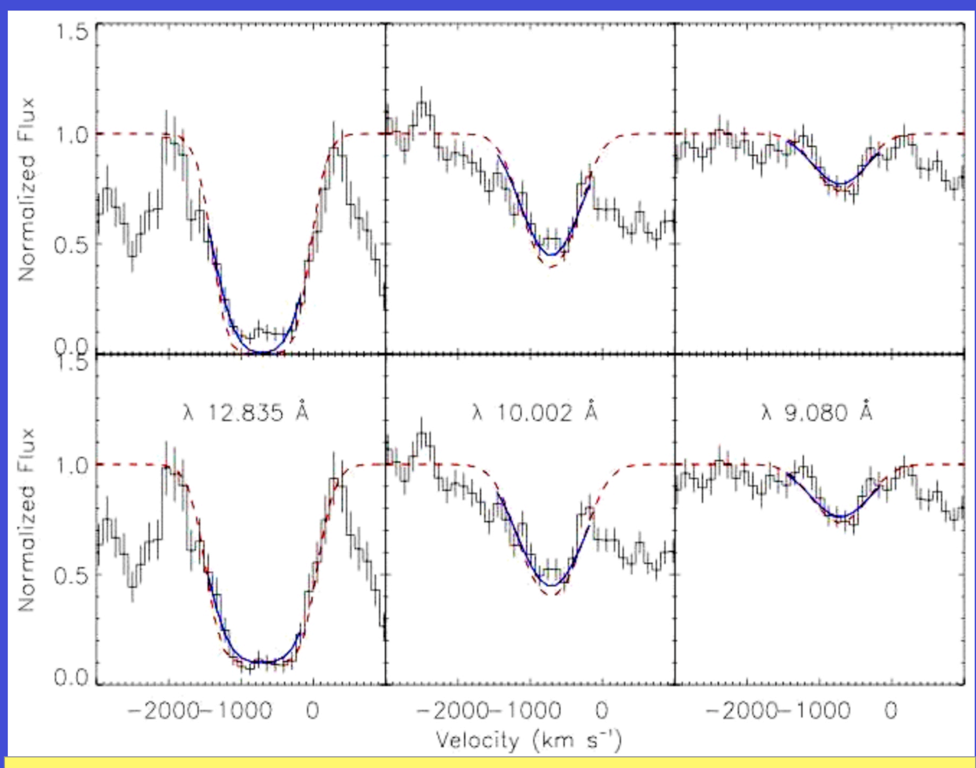

Figure 3: Fe XX lines are fit with full covering (top) and with C=0.9 (bottom). The 12.8 Å feature should be roughly 7.5 times stronger in optical depth than the next strongest pure line at 10 Å.

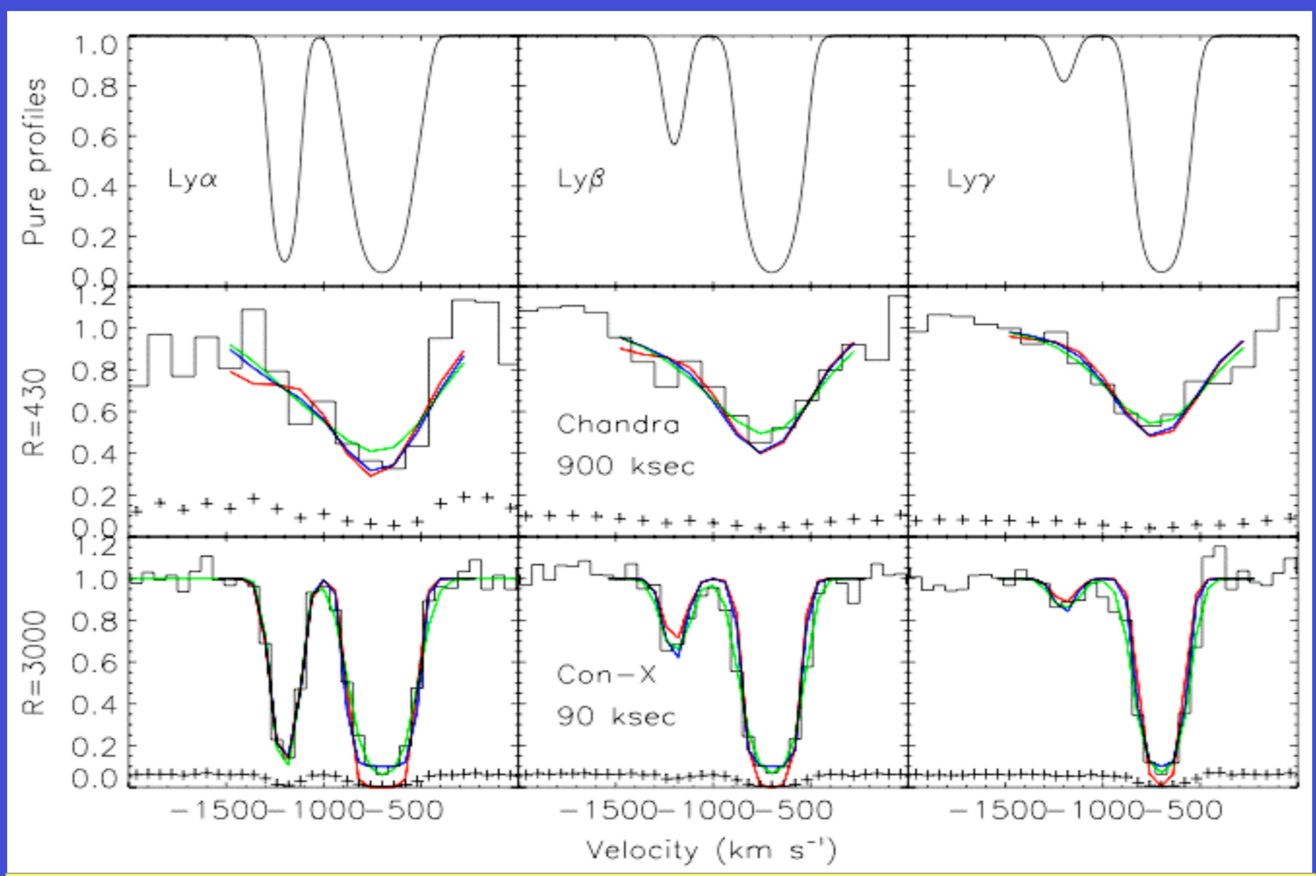

Figure 4: Simulated data of two-component C(v) absorption profiles are fit with full covering (red), C=0.8 (blue), and two-component C(v) (green). Pure absorption profiles are shown on top, MEG simulation in the middle, and Con-X simulation below. Lyman α through γ are plotted from left to right, and plus signs show error. Chandra fits are ambiguous, while the high resolution and signal to noise of Con-X clearly distinguish one model from another.

RESULTS

• **Modeling of the O VII troughs demonstrates unequivocally the existence of partial covering in the NGC 3783 warm absorber.** Modeling of the Fe XX line series adds credibility to the presence of covering factor in line formation. Non-black saturation is seen in parts of the spectrum where the linespread function is not wide enough to cause significant continuum blending.

•Instrument resolution combined with low collecting area in the 1 keV range make it difficult to find a unique covering model fit to the Ne X Lyman series. **Regardless, we find five times higher Ne X column density than previous analysis due to the inclusion of higher order lines.**

• With a 90 ks observation, the assumed R=3000 and 3000 cm^2 effective collecting area of Con-X yield high quality data for which confident covering factor model determination is possible. The MEG resolution and signal to noise impair our ability to distinguish between models confidently.

Constellation-X Compared to Spectroscopic Needs

	Mission Requirement	Off-Plane Grating Projected Capability	Requirement From this Work
Resolution ($\lambda/\delta\lambda$)	500	3000	3000
Effective Area (cm^2)	1000	3000	3000

References

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Conclusions

Constellation-X is the only proposed mission with the potential to properly analyze warm absorbers and outflows.

Constellation-X must significantly exceed its minimum performance requirements. (These were set before the launch of Chandra.)

Constellation-X might achieve the needed goals by use of an off-plane grating array. (This will push even off-plane gratings to their limits.)